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DATA ANALYSIS TECHNIQUES FOR EFFECTIVENESS EVALUATION OF CHEMICAL MUNITIONS

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Effectiveness analysis was performed by BRL using computer-based modeling techniques to support operational testing of chemical munitions. To this end, the BRL standard methodology for unit level analyses, the Army Unit Resiliency Analysis (AURA), was employed. In concert with AURA, the BRL used the Chemical Research, Development and Engineering Center's (CRDEC) Non-Uniform Simple Surface Evaporation (NUSSE) chemical dissemination model. Inputs to NUSSE, describing the dissemination of BIGEYE, were extracted from field trial data collected at Dugway Proving Ground. A BRL graphics program called BIND was used to compare the area coverage and shape of the contamination pattern predicted by NUSSE to the results of the field trial. This comparison demonstrated that NUSSE produced a valid simulation of the chemical munition contamination pattern. This simulation was then used in AURA to model the impact on detailed targets. These data analysis techniques for the BIGEYE effectiveness evaluation have set a precedent in the area of chemical munition effectiveness modeling; and are widely in use throughout CONUS for many chemical weapon effectiveness problems.

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Contents

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1 INTRODUCTION

The Vulnerability/Lethality Division of the BRL has developed data analysis techniques for chemical weapon effectiveness evaluation. These techniques are an enhancement of traditional model verification processes that can be applied to any chemical munition. The analytic procedures include:

- Verification of simulation as compared to actual field trial data for weapon dissemination trials through the use of a computer model;
- Estimation of area coverage on specified targets using the computer generated chemical cloud;
- Assessment of weapon effects on unit level targets using VLD methodology.

Extensive effort has been applied to make the methodology as quantitative and statistically rigorous as possible. These data analysis techniques were developed specifically to address the BIGEYE effectiveness evaluation; however, the methodology is currently being adapted to address other chemical munitions. [1]

2 DISSEMINATION METHODOLOGY

Ongoing chemical simulant trials, conducted at Dugway Proving Ground (DPG), Utah, provide a unique set of experimental data for the dissemination of simulant from variously oriented line sources. The data collected includes dissemination data, optical and radar tracking data of the munition from time of function to impact (Time, Space Position Information - TSPI), and meteorological data. Using these data as input to the Non-Uniform Simple Surface Evaporation (NUSSE) chemical cloud travel model, the process of generating a chemical cloud representative of the field trial is begun. The NUSSE model is used to replicate the liquid (simulant) ground deposition patterns obtained from field trials. This model describes the transport and diffusion of chemical

[1] Himmelheber, Thomas I., U.S. Army Chemical Research, Development and Engineering Center, Hindman, Tracy P. and Klopcic, J. Terrence, U.S. Army Ballistic Research Laboratory, *Effectiveness Evaluation of the BIGEYE (BLU-80/B) Weapon for the Operational Evaluation (OPEVAL) Dissemination Trials (U)*, CRDEC special publication CRDEC-SP-88009, February 1988 (Secret).

agents released into the lower atmosphere. Documentation is contained in a User's Guide [2] and a Model Description. [3] NUSSE is capable of modeling unitary, binary and dual binary agents.

A majority of the NUSSE parameters can be extracted from the DPG data; the remaining parameters are derived mathematically from the initial conditions of the test. The NUSSE parameters have been divided into three categories: geometrical, meteorological, and weapon values.

The geometrical parameters include height of burst (HOB) and line length, which are obtained from the radar tracking data. Line length is measured from the HOB to impact point. These parameters are used to calculate fall angle.

Meteorological data obtained from DPG contains wind speed and direction, Pasquill stability category, and temperature as measured from two tower locations. The wind speed and direction are reported as a thirty minute average. Wind angle (the angle between the munition path and the downwind direction) is calculated using the wind direction and the line of flight of the munition.

Weapon related parameters include vapor and liquid fill weight, and mass median diameter (MMD). The MMD of the simulant droplets is calculated by DPG. The Chemical Research Development, and Engineering Center (CRDEC) provides the distribution parameter for the MMD (sigma D) and the fill weight for the munition.

Other efforts directed toward verification of dissemination codes have concentrated on the accuracy of predicted areas as a function of deposition level by comparing plots of the predicted and measured areas versus deposition levels. These are known as area-dosage plots. Analysts at BRL have developed a set of computer routines to address both area-dosage comparisons and the geometry of the chemical cloud. Additionally, these routines permit the processing of single and multiple weapon dissemination trials. Heretofore, only single weapon dissemination trials could be analyzed and evaluated.

The geometry of the chemical cloud is an important factor to consider when verifying a chemical transport simulation. Agreement between the computer predicted area and the field data using area-dosage plots is not sufficient to validate the simulation if the shape of the clouds shows no agreement. Hence,

[2] Saucier, R., *NUSSE3 User's Guide and Reference Manual*, U.S. Army Chemical Research and Development Center special publication CRDC-SP-86009, March 1986 (Unclassified).

[3] Saucier, Richard, *NUSSE3 Model Description*, U.S. Army Chemical Research, Development and Engineering Center report CRDEC-TR-87046, May 1987 (Unclassified).

the shape of the pattern, in conjunction with the predicted area as a function of deposition level, is considered in the verification process.

BIND is the computer code which is used to compare the NUSSE generated cloud to the field trial. [4] It compares both the area-dosage statistics and two-dimensional pattern shape on the ground; these patterns are referred to as contours (iso-deposition curves). The selected measure of shape is the major axis, where the major axis is defined as the length of the cloud measured in the downwind direction. The square of the major axis is used to give shape the same dimensionality as the area statistic. While it is acknowledged that the behavior of the major axis is less than ideal in the case of highly discontinuous data, the trend of the data appears to be well represented by the axis length. Furthermore, in concert with the area, the major axis determines the overall shape. (That is, no other linear shape measure is independent.)

The statistics chosen for this verification process are the chi square and mean-error statistics. These statistics can be defined as follows:

$$chi\text{-}square = \sum_{i=1}^{K} \frac{W * (D_i - N_i)^2}{D_i^2}$$

$$mean\ error = \sum_{i=1}^{K} \frac{W * (D_i - N_i)}{D_i}$$

Here, N_i is the NUSSE prediction for the i^{th} contour level and D_i is the corresponding field data value. The measures include areas and major axis lengths for each user specified contour level. (Thus, selecting five contour levels for comparison will result in $K = 10$ terms in the above sum.) The weighting factor is $W = 1/K$.

3 EFFECTIVENESS METHODOLOGY

The NUSSE generated cloud is used to assess weapon effects on targets by means of the VLD developed Army Unit Resiliency Analysis (AURA) method-

[4]Klopcic, J. Terrence and Hindman, Tracy P., *Deposition Modeling and Effectiveness Evaluation Using Chemical Weapon Field Trial Dispersion Data*, U.S. Army Ballistic Research Laboratory report BRL-MR-3652, March 1988, (Unclassified).

ology. [5] Simulation of a chemical cloud can be accomplished given plausible NUSSE input even when no test data exist to verify it. The AURA model is a highly detailed unit level model for the evaluation of unit mission performance on the integrated battlefield. Among other things, personnel exposures to specific liquid deposition levels and unit performance as a function of time can be assessed. A variety of tactical and strategic targets have been developed for use in the AURA model. For illustrative purposes, an airfield will be discussed.

In developing a functional description for the target unit, the specific, quantified mission(s) to be performed by the unit must first be determined. The unit is then evaluated in terms of its ability to perform this mission(s). The target is described in detail, with each individual person and piece of supportive equipment given specific coordinates. For example, the airfield is 2400 meters by 1600 meters and has 1150 personnel deployed.

The unit is described as a series of tasks that are needed to carry out its mission, which requires quantitative measure of these tasks (referred to as links). A unit can perform a variety of missions. Often, the mission(s) can be accomplished in numerous ways. For example, the mission of the airfield is to generate 108 sorties per 24 hour period. Aircraft and pilots are required to perform this mission, hence the links "aircraft" and "pilot" are used to describe these tasks. Many more links are required to fully describe this mission. These tasks are performed by designated personnel and/or equipment, including appropriate substitutions when primary personnel/equipment are not available. The links are then interrelated to achieve the specific mission.

Weaponeering, the determination of weapon delivery parameters, provides the necessary delivery information to simulate the threat. For example, the employment of BIGEYE in an actual attack would have involved more chemical munitions then are tested in any one particular trial, hence the need for developing a realistic threat scenario. A "stick" of munitions can be developed, one of which can be the munition actually delivered in the field trial. This aides in determining the optimum aiming and delivery techniques, while at the same time providing realism to the scenario.

Chemical protection as a countermeasure can be examined using AURA. The protective status is referred to as Mission Oriented Protective Posture or MOPP. There are five levels of protection, with MOPP Zero representing no protection and MOPP4 representing full protection. Two scenarios can be

[5] Klopcic, J. Terrence and Roach, Lisa K., *An Introduction to the Army Unit Resiliency Analysis (AURA) Methodology, Volume I*, U.S. Army Ballistic Research Laboratory report BRL-MR-3384, September 1984 (Unclassified).

examined: personnel remaining in the initial posture,MOPP Zero, throughout the analysis, or personnel assuming an alternate posture upon weapon initiation. The time required to assume this posture, referred to as MOPP time, is user specified. A higher level of MOPP provides increased protection for personnel, yet at the same time degrades performance. Specific levels of degradation are based upon one's assigned duties and MOPP status. Examination of these two scenarios provides an upper and lower limit on personnel casualties.

Two measures of effectiveness that can be addressed are exposure of personnel and degradation of the unit mission. Personnel exposure is evaluated at user specified deposition levels. Unit degradation is based upon the unit's ability to complete its mission. As previously stated, the airfield's mission was to generate a total of 108 sorties per 24-hour period. Given an effectiveness value of 50 percent, the unit can only generate 54 sorties per 24-hours. For unprotected troops (MOPP Zero), degradation is due to the effect of chemical dosages received by personnel. For troops assuming protective posture, degradation can be due to the wearing of MOPP as well as to chemical dosages received by personnel.

4 SUMMARY

The effectiveness analysis was performed using computer-based modeling techniques to support operational testing of chemical munitions. To this end, the VLD standard methodology for unit level analyses, the Army Unit Resiliency Analysis (AURA), was employed. In concert with AURA, the Chemical Research, Development and Engineering Center's (CRDEC) Non-Uniform Simple Surface Evaporation (NUSSE) chemical dissemination model is used to describe the chemical threat. Inputs to NUSSE can be extracted from field trial data collected at Dugway Proving Ground. A BRL graphics program called BIND is used to compare the area coverage and shape of the contamination pattern predicted by NUSSE to the field trial. This model addresses both area-dosage as well as geometry of the chemical cloud. The chemical cloud simulation is then used in AURA to model the impact of chemical weapons on unit level targets that are representative of foreign operations. Personnel casualties and unit effectiveness are assessed by AURA. These data analysis techniques for effectiveness evaluation have set a precedent in the area of chemical munition effectiveness modeling. They are widely in use throughout CONUS for many chemical weapon effectiveness problems and are readily adaptable for analysis of other chemical munitions.

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